Continuous-wave dual-wavelength Nd:YVO₄ laser at 1066.4 nm and 1083.8 nm

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ABSTRACT
A LD end-pumped continuous-wave (CW) Nd:YVO₄ laser with synchronous dual-wavelength operation at 1066.4 nm and 1083.8 nm is demonstrated. The threshold at 1083.8 nm is only 0.75 W due to the high Nd³⁺-doping-concentration of a Nd:YVO₄ gain crystal. At a pump power of 3.9 W, the maximum CW total output power of 480 mW is obtained. The full width at half maximum (FWHM) at 1066.4 and 1083.8 nm are 2.2 nm and 2.1 nm, respectively.

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1. Introduction

Efficient and compact all-solid-state lasers of simultaneous emission at dual-wavelength exhibit versatile applications in different fields, including laser remote sensing, optical communications, laser radar, environmental monitoring, terahertz radiation generation, and medical instrumentation [1–4]. Dual-wavelength lasers operating in Nd³⁺-doped gain materials, such as Nd:YSGG [1], Nd:Mg:LiTaO₃ [2], Nd:YAG [3,4], Nd:GdVO₄ [5] and Nd:YVO₄, have been previously reported. The Nd:YVO₄ crystal has been identified as one of the most promising gain medium for all-solid-state lasers because of its large stimulated-emission cross-section and high pump absorption coefficient [6,7].

In 2000, Chen reported a dual-wavelength CW Nd:YVO₄ laser that operated at the wavelengths 1064 nm and 1342 nm [8]. In 2006, Zhou experimentally demonstrated a dual-wavelength CW Nd:YVO₄ laser simultaneously operating at 1342 and 1386 nm [9]. In 2010, Lü presented for the first time a dual-wavelength Nd:YVO₄ laser operation at 1064 and 914 nm [10]. In this paper, a CW Nd:YVO₄ laser with synchronous dual-wavelength operation at 1066.4 nm and 1083.8 nm is obtained. The threshold at 1083.8 nm is only 0.75 W, and the maximum CW total output power is 480 mW.

2. Experiment setup

The experiment setup is shown schematically in Fig. 1. The pump source of this laser system is a fiber-coupled LD with a center wavelength of 808 nm at 20 °C. The pump light is focused by focusing optics to a Nd:YVO₄ laser crystal. The c-cut 2 at.% Nd³⁺-doped Nd:YVO₄ crystal has a dimension of 3 × 3 × 5 mm³. The left facet of the laser crystal (M₉) is anti-reflection (AR) coated at 808 nm and high-reflection (HR) coated at 1000–1100 nm (R > 99.9%) to act as a cavity mirror (input mirror); the other facet is AR coated at 1050–1100 nm to reduce the cavity loss. The output coupler (M₁₀) has a transmission at 1066 nm (T = 0.5%) slightly higher than that at 1083 nm (T = 0.3%), and the cavity length is about 25 mm. The output near-infrared spectrum is observed with a wide-range optical spectrum analyzer (Yokogawa AQ6370). The visible spectrum is measured with a fiber optical spectrometer (AvaSpec-2048).

3. Experiment results and discussion

First, we observe the optical spectrum of the CW Nd:YVO₄ laser as shown in Fig. 2. When the pump power reaches to 0.34 W, the wavelength at 1066.4 nm is appeared. Luckily, the other line at 1083.8 nm is observed, which also corresponds to the transition of 4F₃/2 → 4I₁₁/₂ when the pump power reaches to 0.75 W. The threshold at 1083.8 nm is so low due to the high Nd³⁺-doping-concentration of Nd:YVO₄ crystal in this experiment. The high concentration is easy to absorb much more pump energy, and achieve high necessary population inversion. Furthermore, we also test the fine spectrum of 1066.4 nm and 1083.8 nm at the pump...
power of 3.9 W. The FWHM of dual-wavelength spectrum is about 2.2 nm and 2.1 nm, respectively.

It is difficult to measure their output power individually. Employed with a power meter (Thorlabs PM100D), the total output power at the 1066.4 nm and 1083.8 nm with respect to the pump power is shown in Fig. 3. Under the pump power of 3.9 W, the maximum total output power is 480 mW with an optical conversion efficiency of 12.3%. Deduced from the relative intensity of the optical spectrum as shown in Fig. 2, the maximum powers at 1066.4 nm and 1083.8 nm should be about 215 mW and 265 mW, respectively. The relative intensity of the two lines does not keep constant. There is a slight jitter which is attributed to the mode competition. However, the total output power is very stable.

The optical conversion efficiency at different pump power is also shown in Fig. 3. The plane–plane cavity has relatively high loss and leads to the small conversion efficiency at first. With the increase of the pump power, population inversion becomes stronger, which explains the increase of the conversion efficiency. The maximum conversion efficiency is 14.2% at the pump power of 3.0 W. However, considering the serious thermal effect of the Nd:YVO4 crystal, the conversion efficiency diminishes when the pump power is above 3.0 W.

A 3-mm-long KTP crystal (θ = 90°, ϕ = 23.4°) is used to generate green laser. The optical spectrum of second-harmonic generation (SHG) and the sum-frequency mixing (SFM) of the dual-wavelength line is shown in Fig. 4. The SHG of the dual-wavelength line is 533.2 nm and 541.9 nm, respectively, and the SFG of the two wavelengths is 537.5 nm.

4. Conclusion

In summary, we have demonstrated CW dual-wavelength Nd:YVO4 laser at 1066.4 nm and 1083.8 nm. At the pump power of 3.9 W, the maximum output power of 480 mW is obtained. The threshold at 1083.8 nm is only 0.75 W due to the high Nd3+-doping-concentration of Nd:YVO4 crystal. The FWHM at 1066.4 and 1083.8 nm are approximately 2.2 nm and 2.1 nm, respectively. Furthermore, a tri-wavelength green line is observed when a KTP crystal is inserted into the laser cavity.

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